AIRCRAFT FLIGHT DATA ACQUISITION AND TRANSMISSION SYSTEM

INVENTORS
John F. Grabowsky
David Ray Stevens

CROSS-REFERENCE TO RELATED APPLICATIONS

(Not Applicable)

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

(Not Applicable)

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is directed generally to an aircraft flight data acquisition and transmission system and, more particularly, to an on-board cellular data transmission system.

Description of the Background

It is common for aircraft to generate records of data relating to flight and performance parameters for each flight of the aircraft. The data typically relate to parameters such as air speed, altitude, vertical acceleration, heading, time, etc. The data are utilized in the event of an accident or a near-accident and to assist in maintenance of the aircraft by detecting faulty components or gradual deterioration of a system or component, to assist in reviewing crew performance, and to assist in logistical planning activities such as scheduling and routing.

Aircraft data are typically gathered by a digital flight data acquisition unit (DFDAU). The DFDAU typically stores the data on magnetic or magnetic-optical media. When the aircraft lands, ground personnel board the aircraft, remove the media, and mail the media to a flight operations center (FOC). The manual removal and posting of the data adds a

significant labor cost, yields less than desirable data delivery reliability, and results in a significant time delay before the data are useful for analysis.

It is known to use radio frequency (RF) transmissions to transmit data relating to an aircraft. Such teachings, however, require substantial investments to construct the RF transmission systems required for such a system to work. Furthermore, it is very expensive to create redundancy in such a system.

It is also known to transmit data relating to an aircraft via a telephone system located in a terminal. Such a system, however, requires that the aircraft be docked at the gate before transmission begins, thereby resulting in a substantial delay in the transmission. Furthermore, such a system requires an added step of transmitting the data from the aircraft to the terminal telephone system, increasing the cost of installing, operating, and maintaining such a system.

Thus, there is a need for an aircraft data transmission system that automatically transfers flight data from an aircraft to a flight operations center with little or no human involvement and which relies on a reliable wireless delivery system.

SUMMARY OF THE INVENTION

The present invention is directed to an aircraft data transmission system used with an aircraft having a data acquisition unit. The system includes a communications unit located in the aircraft and in communication with the data acquisition unit. The system also includes a cellular infrastructure in communication with the data communications unit after the aircraft has landed. The system further includes a data reception unit in communication with the cellular infrastructure.

The present invention represents a substantial advance over prior aircraft data acquisition and transmission systems. For example, the present invention has the advantage that it requires little expense to implement because it uses well-known technology and the

cellular infrastructure which is already in place. The present invention also has the advantage that it can transmit data over multiple parallel channels to achieve the necessary transmission bandwidth and achieve a low data transmission time. The present invention has the further advantage that it does not require a dedicated data link between the aircraft and the flight operations center and/or an airport terminal.

BRIEF DESCRIPTION OF THE DRAWING

For the present invention to be clearly understood and readily practiced, the present invention will be described in conjunction with the following figures, wherein:

FIG. 1 illustrates an aircraft data acquisition and transmission system;

FIG. 2 is a block diagram illustrating a more detailed embodiment of the system illustrated in FIG. 1;

FIG. 3 is a block diagram illustrating data flow through the system illustrated in FIG. 2;

FIG. 4 is a flowchart illustrating a method carried out by the gatelink processor in the aircraft;

FIG. 5 is a flowchart illustrating a method of performing the start primary data thread step of FIG. 4;

FIG. 6 is a flowchart illustrating a method of performing the start secondary data threads step of FIG. 5;

FIG. 7 is a flowchart illustrating a method of operating the gatelink processor in the flight operations center;

FIG. 8 is a flowchart illustrating a method of performing the initialize session process step of FIG. 7;

FIG. 9 is a flowchart illustrating a method of performing the data message process step of FIG. 7;

FIG. 10 is a flowchart illustrating a method of performing the end session process step of FIG. 7; and

FIG. 11 is a block diagram illustrating another embodiment of the system illustrated in FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

It is to be understood that the figures and descriptions of the present invention have been simplified to illustrate elements that are relevant for a clear understanding of the present invention, while eliminating, for purposes of clarity, other elements found in a typical communications system. It can be recognized that other elements are desirable and/or required to implement a device incorporating the present invention. For example, the details of the cellular communications infrastructure, the Internet, and the public-switched telephone network are not disclosed. However, because such elements are well known in the art, and because they do not facilitate a better understanding of the present invention, a discussion of such elements is not provided herein.

FIG. 1 illustrates an aircraft data acquisition and transmission system 10. An aircraft 12, which has stored flight data, is illustrated after landing. The aircraft 12 transmits flight data as cellular communications signals to a cellular infrastructure 14. The cellular infrastructure 14 acts as a communications channel to the communications medium 16. A flight operations center 18 is connected to the medium 16 by any conventional connectivity medium such as, for example, a leased line. Once the cellular connections are made via the medium 16 data can flow bidirectionally from or to the aircraft.

FIG. 2 is a block diagram illustrating a more detailed embodiment of the system 10 illustrated in FIG. 1. The aircraft 12 includes a data system 19 having a data acquisition unit 20. The data acquisition unit 20 includes a digital flight data acquisition unit (DFDAU) processor 22, which includes a storage media for storing flight data in a digital format. The

DFDAU processor 22 receives signals from sensors 24 which sense parameters such as air speed, altitude, vertical acceleration, heading, time, etc. The flight data are transferred to a communications unit 26 via a bus 28. The bus 28 is connected to an I/O interface 30 in the communications unit 26. The I/O interface 30 can be a standard bus interface such as, for example, an ARINC 429 bus interface.

The I/O interface 30 is connected to a gatelink processor 32. The processor 32 can be a general purpose processor such as a personal computer, a microprocessor such as an Intel Pentium® processor, or a special purpose processor such as an application specific integrated circuit (ASIC) designed to operate in the system 10. The processor 32 is responsive to a weight-on-wheels signal, which acts as an interrupt signal to signal the processor 32 to initiate transmission or reception of the data when the aircraft 12 has landed. Upon receipt of the weight-on-wheels signal from the landing gear of the aircraft 12, the processor 32 prepares the flight data for transmission and transmits the data to a multi-port serial card 34. Each I/O port of the card 34 is attached to a cell channel which can open, sustain, and close a physical, over-the-air channel to the cellular infrastructure 14. The cell channels 36 can transmit simultaneously and can thus transmit data in parallel. Each cell channel 36 is connected to an antenna matching network and a post amplifier (not shown). An antenna 38 is installed in the aircraft 12 so as to optimize free space radiation to the cellular infrastructure 14.

The data are transmitted over a cellular airlink using the physical layer modulation of the cellular infrastructure 14. The cellular infrastructure 14 includes an antenna 40, which is within free-space radiating range of the aircraft 12. The antenna 40 is connected to a base station transceiver subsystem 42. The subsystem 42 is connected to a base station controller 44 which has a direct connection via a router (not shown) to the Internet 45. The flight data are transmitted via the Internet 45 to the flight operations center 18.

A local router 46 in a data reception unit 47 of the flight operations center 18 is connected to the Internet 45, such as via a connection to the backbone of the Internet 45. The router 46 connects a local area network 48 to the Internet 45. The local area network can be of any type of network such as, for example, a token ring network, an ATM network, or an Ethernet network. A gatelink processor 50 is connected to the network 48 and receives the flight data for storage in an attached storage unit 52. The storage unit 52 can be any type of unit capable of storing data such as, for example, a disk array or a tape drive. The storage unit 52 makes the flight data available to data analysis applications 54 which can analyze and/or report the flight data to a user.

Data transfer can also occur from the flight operations center 18 to the aircraft 12. The data are transmitted via the Internet 45 and the cellular infrastructure 14 and received by the antenna 38. The serial card 34 receives the data from the cell channels 36 and the processor 32 outputs the data, via the I/O interface 30, to avionics 55.

FIG. 3 is a block diagram illustrating data flow through the system 10 illustrated in FIG. 2. The flight data is stored in the DFDAU processor 22 as a stored file 56. An application layer 58 of an operating system 60 of the gatelink processor 32 compresses, encrypts, and segments the data. The operating system 60 can be any type of operating system suitable such as, for example, UNIX. A typical stored file may be compressed from approximately 40 Mbytes to approximately 4 Mbytes. Compression may be done by any compression method such as, for example, the method embodied in the PKZIP® compression utility, manufactured by PKWARE, Inc. Encryption can be accomplished using any suitable asymmetric (public key) or symmetric encryption method such as, for example, the method embodied in Data Encryption Software (DES), manufactured by American Software Engineering or the methods in the RC2, RC4, or RC5 encryption software manufactured by RSA Data Security, Inc. During segmentation individual datagrams of, for example, 1024 bytes are formed and indexed for subsequent reassembly.

The operating system 60 passes the datagrams to a network layer 62 which constructs UDP/IP packets from the datagrams by adding message headers to the datagrams. The network layer 62 then routes the packets to one of up to 16 peer-to-peer protocol (PPP) threads running within the operating system 60 at a data link layer interface 64. The PPP threads convey the packets to the multi-port serial card 34 for transmission to the backbone 66 of the Internet 45 via the cell channels 36 to the cellular infrastructure 14. The packets are received from the Internet 45 by the local router 46 in the flight operations center 18. The network layer 62 receives acknowledgments of received packets from the gatelink processor 50 in the flight operations center 18. The network layer 62 also re-queues packets that are dropped before reaching the gatelink processor 50.

The local router 46 in the flight operations center 18 receives the packets and routes them to the gatelink processor 50. A local network interface 68 receives the packets and a data link layer interface 70 of an operating system 72 passes the packets to a network layer 74 of the operating system 72. The operating system 72 can be any type of suitable operating system such as, for example, UNIX. The network layer 74 sends acknowledgments of successful packet deliveries to the gatelink processor 32. The network layer 74 also removes the UDP/IP headers and passes the datagrams to an application layer 76. The application layer 76 reassembles, decrypts, and uncompresses the datagrams to restore the flight data to its original form. The application layer then passes the data to a stored file 78 in the storage unit 52. The functions performed by the aircraft 12 and the flight operations center 18 are similarly interchangeable when data is transferred from the flight operations center 18 to the aircraft 12.

FIG. 4 is a flowchart illustrating a method carried out by the gatelink processor 32 in the aircraft. At step 82, the gatelink processor 32 receives a weight-on-wheels interrupt which signals that the aircraft has landed, and the data transfer is initiated. The application layer 58 compresses the flight data at step 84 and encrypts the data at step 86. At step 88,

the data is segmented into datagrams and UDP/IP packets are constructed. The packets are then placed in a packet queue. The packets are then ready for transmission as a fixed number of threads, corresponding to the number of cell channels 36. At step 90, the primary data thread is started to make the initial call and open the communications channel to the flight operations center 18. A wait state at step 92 is invoked for a predetermined period of time (5 sec.) and at step 94, the processor 32 determines if any threads are active, i.e. if there are any packets that haven't been transmitted or have been transmitted and dropped. If there are no packets remaining, the method is completed at step 96. If there are packets remaining, the method enters the wait state at step 92 and subsequently determines if any threads are active at step 94.

FIG. 5 is a flowchart illustrating a method of performing the start primary data thread step 90 of FIG. 4. At step 98, the point-to-point protocol (PPP) connection is initiated for the primary data thread through one of the cell channels 36 and the gatelink session is initiated at step 100. The secondary data thread transmissions are started at step 102. At step 104, it is determined if any packets are left in the primary data thread to be transmitted. If so, the next packet in the primary data thread is transmitted at step 106. If no packets are left to transmit in the primary data thread as determined at step 104, it is determined if any of the secondary data threads are active at step 108. If so, the process returns to step 104 and repeats step 108 until no threads are active. If no threads are active, the gatelink session is ended at step 110 and the PPP connection for the primary data thread is closed at step 112. At step 114, the primary data thread step 90 is completed.

FIG. 6 is a flowchart illustrating a method of performing the start secondary data threads step 102 of FIG. 5. The method is carried out in parallel for each secondary data thread. At step 116, the thread is set to active so that the processor 32 can determine if any threads are active at step 108 of FIG. 5. The PPP connection for the secondary data thread being transmitted is initiated at step 118. At step 120, it is determined if any packets remain

in the data thread. If so, the packet is transmitted at step 122. If no packets remain in the data thread, the PPP connection is closed at step 124 and the thread is set to inactive at step 126. The method is completed at step 128.

FIG. 7 is a flowchart illustrating a method of operating the gatelink processor 50 in the flight operations center 18. At step 130, a socket is opened to allow the operating system 72 in the processor 50 to receive and transport messages across the Internet 45. At step 132, the processor 50 waits for a message from the Internet ~~16~~ 45. When a message is received, the processor 50 determines if the message is a session initiatialization message at step 134. If the message is a session initialization message, the processor 50 executes the session initiatialization process at step 136. If the message is not a session initiatialization message at step 134, the processor 50 determines if the message is a data message at step 138. If the message is a data message, the processor 50 executes the data message process at step 140. If the message is not a data message, the processor 50 determines if the message is an end session message at step 142. If the message is an end session message, the processor 50 executes the end session process at step 144 and then returns to step 132 to wait for additional messages..

EWJ 1/27/00

FIG. 8 is a flowchart illustrating a method of performing the initialize session process step 136 of FIG. 7. The processor 50 allocates buffer space for subsequent data reception at step 146. The processor 50 then sends a session initialized data acknowledgment to the processor 32 at step 148. At step 150, the flow returns to step 132 of FIG. 7.

FIG. 9 is a flowchart illustrating a method of performing the data message process step 140 of FIG. 7. At step 152, the received data message is copied to a buffer and an acknowledgment of the data received is sent at step 154. At step 156, the flow returns to step 132 of FIG. 7.

FIG. 10 is a flowchart illustrating the steps included in the end session process step 144 of FIG. 7. At step 158, the checksum is computed for the received data to check the

integrity of the data. The checksum is checked at step 160 and, if it is correct, the processor 50 saves the buffer to a temporary file at step 162. The processor 50 then decrypts the file at step 164 and uncompresses the file at step 166. The processor 50 sends an end session acknowledge message to the processor 32 at step 168 and at step 170, the flow returns to step 132 of FIG. 7. If the checksum is not correct, the processor 50 sends an unsuccessful end session message, which notifies the processor 32 to resend the data.

FIG. 11 is a block diagram illustrating another embodiment of the system 10 illustrated in FIG. 1. The operation of the system 10 of FIG. 11 is similar to that described in conjunction with the system 10 of FIG. 2. However, the flight data is transmitted from the cellular infrastructure 14 to the flight operations center 18 via the public-switched telephone network 172. A modem bank 174 receives the data via the PSTN 172. The data is then routed by the router 46 to the processor 50 via the network 48. The modem bank 174 can have a modem dedicated to receive data transmitted by one of the cell channels 36.

While the present invention has been described in conjunction with preferred embodiments thereof, many modifications and variations will be apparent to those of ordinary skill in the art. For example, although the system has been described hereinabove as transferring data from the aircraft, the system can also be used to transfer data to the aircraft with no modifications in the system. Also, the system may be used to transmit data while the aircraft is in flight. Furthermore, the system may be used without encryption and without data compression prior to sending data. The foregoing description and the following claims are intended to cover all such modifications and variations.